SPEED SENSORLESS FIELD ORIENTED CONTROL OF AC INDUCTION MOTOR
USING MODEL REFERENCE ADAPTIVE SYSTEM

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DEDICATION

I would like to thank my parents JAMEEL ISMAEL and ILHAM ABDUL HUSSIEN for giving me ethical support while I were doing this project. They always guided me to make sure I could finish my project on time and complete it successfully.

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ABSTRACT

In order implement the vector control technique, the motor speed information is required. Incremental encoder, resolvers and tachogenerator, are used to reveal the speed. These sensors require careful mounting and alignment and special attention is required with electrical noises. Sensorless speed vector control is greatly used and applied in induction machine drives instead of scalar control and vector control for their robustness and reliability, and very low maintenance cost. In this project MRAS based techniques are used to estimate the rotor speed based on rotor flux estimation, the estimated speed in the MRAS algorithm is used as a feedback for the vector control system. The model reference adaptive control system is predicated on the comparison between the outputs of adjustable model and reference model. The error between them is employed to drive a suitable adaptation mechanism which generates the estimated rotor speed for the adjustable model. And indirect vector control scheme controls the flux and torque by restricting the torque and flux errors with respective hysteresis bands, and motor flux and torque are controlled by the stator voltage space vectors using optimum inverter switching table. Modeling and simulation of the induction machine and the vector control drives implemented in MATLAB/SIMULINK. Simulation results of proposed MRAS and indirect vector control technique are presented.

ABSTRAK

Teknik kawalan vektor memerlukan maklumat kelajuan motor. Pengekod tambahan, pemecah stres dan tachogenerator digunakan untuk mendedahkan kelajuan. Sensor ini perlu pemasangan, penjajaran yang berhati-hati dan perhatian khusus bersama bunyi elektrik. Kawalan vektor kelajuan tanpa sensor sangat berguna dan digunakan dalam pemacu mesin induksi dan bukannya kawalan skalar dan kawalan vektor untuk kekukuhan, kebolehpercayaan, dan Kos penyelenggaraan yang sangat rendah. Dalam projek ini, teknik berasaskan MRAS digunakan untuk menganggarkan kelajuan rotor berdasarkan anggaran aliran rotor, kelajuan yang dianggarkan dalam algoritma MRAS digunakan sebagai maklum balas untuk sistem kawalan vektor. Model kawalan adaptif rujukan model adalah berdasarkan perbandingan antara output model Laras dan rujukan. Ralat di antara mereka digunakan untuk memacu mekanisme penyesuaian yang sesuai yang menghasilkan kelajuan rotor yang dianggarkan untuk model Laras. Skema kawalan vektor tidak langsung mengawal fluks dan tork dengan menghadkan kesilapan tork dan fluks dengan band histeresis masing-masing, Fluks motor dan tork dikawal oleh vektor ruang voltan stator menggunakan jadual penukaran inverter optimum. Pemodelan dan simulasi mesin induksi dan pemacu kawalan vektor yang dilaksanakan di MATLAB / SIMULINK. Hasil simulasi MRAS yang dicadangkan dan teknik kawalan vektor secara langsung dibentangkan. Hasil kajian menunjukkan kestabilan dan ketepatan untuk teknik yang dicadangkan dan juga menunjukkan ciri-ciri operasi beban yang baik.

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LIST OF SYMBOLS

Rr	Rotor Resistance
Rr’	Rotor Resistance Referred to Stator side
Im	Magnetizing Current
s	Slip
ωs	Synchronous Speed
ωm	Rotor Speed (Machine Speed)
f	Supply Frequency
p	No. of Poles
T	Torque Developed by the motor
ωref	Reference Speed
ωsl	Slip Speed
Vqs	q-axis Stator Voltage with stationary frame
Vds	d-axis Stator Voltage with stationary frame
Iqs	q-axis Stator Current with stationary frame
Ids	d-axis Stator Current with stationary frame
Iqr	q-axis Rotor Current with stationary frame
Idr	d-axis Rotor Current with stationary frame
Fds	d-axis Stator flux with stationary frame
Fqs	q-axis Stator flux with stationary frame
Fdr	d-axis Rotor flux with stationary frame
Fqr	q-axis Rotor flux with stationary frame
Fs	q-axis Rotor flux with stationary frame

Ls	Stator Self-Inductance
Lr	Rotor Self-Inductance
Lm	Stator Mutual-Inductance

LIST OF ABBREVIATIONS

IM	Induction Motor
MMF	Stator Resistance

CHAPTER 1

INTRODUCTION

1.1 Project Background

In modern society, motor drive system is widely employed in numerous industries as energy convertor for changing electrical energy into mechanical energy for the last many decades [1]. In addition, it is widely applied to various fields such as home appliances systems such as washing machine and air conditioner s and refrigerators and transportation system such as aviation and electric trains, electric vehicles and agriculture and medical and national defense. The main purpose of any machine control system is to extract endurance the energy in an efficient way and in a wide speed range control [2]. With the development in vector control method, the induction machine become a preferable replacement for dc machines. Even though induction machine categorized by their Simplicity and robustness of their structure, inexpensive to manufacture, easy to manufacture for high power, semi-permanent in life. With the development in vector control method, the induction machine become a preferable replacement for dc machines. Even though induction machine categorized by their Simplicity and robustness of their structure, inexpensive to manufacture, easy to manufacture for high power, semi-permanent in life. However, an induction machine needs a lot of complicated schemes than dc motors because of its highly nonlinear and coupled dynamic structure [3]. Open-loop vector control of induction motor is step up from V/F increasing voltage as frequency increases it is great for fans and pumps but for more advanced application such as spinal control or material handling we will need closed loop control to precisely control the speed and torque of the motor. Therefor highly developed control schemes are needed to improve the performance of induction drive comparable with dc motors. recent development in microelectronics and power electronics, powerful and cheap microcontroller, the control of ac motor become very perfect and comparable to dc motor. In the last few decades, the vector control theory has been receiving much attention because of its better steady and dynamic performance over conventional control schemes in controlling the speed and torque parameter. The most extensively used induction motor drive vector control method is the field oriented control (FOC) [4]. Conventional field oriented control systems need a position sensor to get the speed information and perform high performance torque control of induction motor. Usually we can install the speed sensor on the shift of the rotor to measure the speed, however The disadvantages of using a speed sensor are increased manufacturing cost and deterioration of the reliability, increase the driven motor dimension, wiring, decrease the dependability of the induction motor, additionally, it limits the mechanical design and may cause a problem in the aerodynamic design. Moreover, the sensors need to be connected to a special cable which increase which increase the magnetic susceptibility of the induction motor [5] [6]. However, there are alternatives. Sensor less ac induction motor drive solution has become the most prospective method to overcome the issues comes from introducing shift speed sensor in the induction machine. The speed sensor less vector control (SSVC) is presented first by G Maeder 4 and R Joetten in 1983, who prompted the development of alternating current (AC) transmission technology up to a new level [7]. The study of speed senseless control of the IM has undergone through maturing years when new techniques came into introduction to improve the previous techniques. The motivation is to find one method that can cater the entire problem related to speed sensor less IM. To get good performance of sensor less vector control [8] [9], a variety of speed estimation techniques have been proposed. such as adaptive full order observer, direct calculation method [10], extended kalman filter (EKF), Luenberger observer, [11], sliding mode observer, slot harmonics [12], artificial intelligence neural network [13], estimators using fuzzy logic control [14], model reference adaptive system(MRAS) [15] [16]. Among the above different speed estimation schemes MRAS schemes are popular and has been widely used in ac speed control system due to its relative simplicity and good performance characteristics and needs low computation power and have high speed of adaptation even at zero speeds. Model reference adaptive system (MRAS) uses two different sets input variables and two different structured motor models to estimate the speed of electric machine. the module that does not involve the estimated variables is called the reference model, which is independent of rotor speed calculates the state variables x. and the model that contains variables that change over time is called the adjustable model, which dependent on rotor speed, estimates the state variables $\bar{x}$. The error ε is then used to drive an adaptation mechanism which generates the estimated speed, ω, for the adjustable model as shown in the block diagram of Figure 1.1[16]

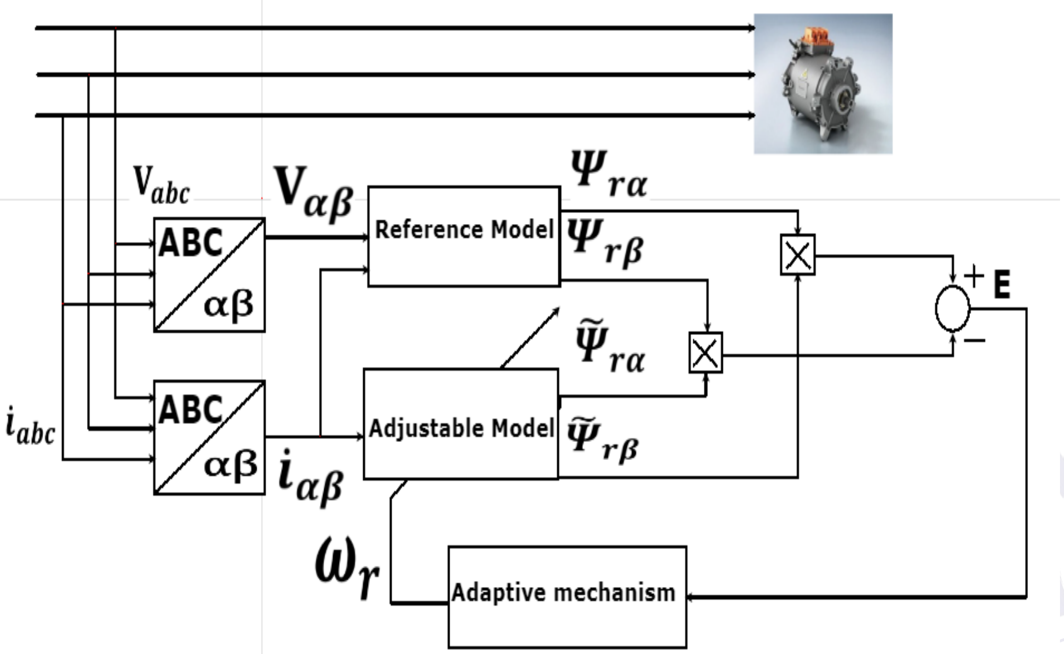

Figure 1.1: Rotor speed estimation structure using MRAS

1.2 Motivation

The first driving factor for senseless field-oriented control on three phase induction motor is reducing the system cost, sensors can cause problems in manufacturing and reliability, and there are also appear a difficulty in installing and maintaining the sensors. In addition, it limits the mechanical design and may cause a problem to the aerodynamic design, and they require special wiring harnesses and connectors which increase the overall system cost [17].

The second driving factor is the noticeable amelioration of the energy efficiency of an ACIM motor. By using FOC We can get very high efficiency up to ninety-five percent. This has a Great effect on reducing power losses, improve motor dynamic response, less heat dissipation and less noise. For instance, in applications like electric cars and electric buses and washing machine and fans and water and fuel pumps must operate very silently, otherwise the mechanical vibration sounds can have transmitted to the air or water pipes and causes the solid-borne noise within the hole building [18].

1.3 Problem statement

Opposite to the benefits and motivation of field-oriented control drive application, come into sight challenges and problems are very necessary to reveal. As it is previously mentioned in chapter one, one of the crucial aspects is the need to use position sensor to obtain the reliable position or (speed) information. Traditionally used mechanical sensors installed on the shift, there appear difficulty in installing and maintaining the sensors. Because of it some applications require a compact design; others extremely hot, in corrosive, water ingress, vibration, or otherwise hazardous environments necessitate that designs be free of additional wiring (for sensors or devices mounted on the shift and so on). Sensor less field-oriented control benefits design in both of these situations. This has few benefits, mostly all relating to the cost. It allows as to eliminate the cost of the encoder and the cable, more robust solution, increasing the reliability, and then finally it can be beneficial for long cable runs, where the cable has to be routed for a long distance from the cabinet to the motor.

1.4 Objectives

The main objectives of this thesis can be divided into three main parts which are:

1- Design, Sensor Less AC induction motor speed control system in MATLAB/SIMULINK Based on Model Reference Adaptive System.

3. Evaluate the performance sensor less vector control drive during load and without load.

1.5 Scope

Scope of this project including:

1- Induction motor structure and their modelling

The structure of induction motor is studied and mathematical model of induction motor is derived.

2- Speed estimator design for induction motor

The mathematical equation of induction motor is then transforms into differential equation to design the estimator.

3-Computer simulation the simulation is done by using MATLAB Simulink

And the process of the work is shown in Figure 1.6

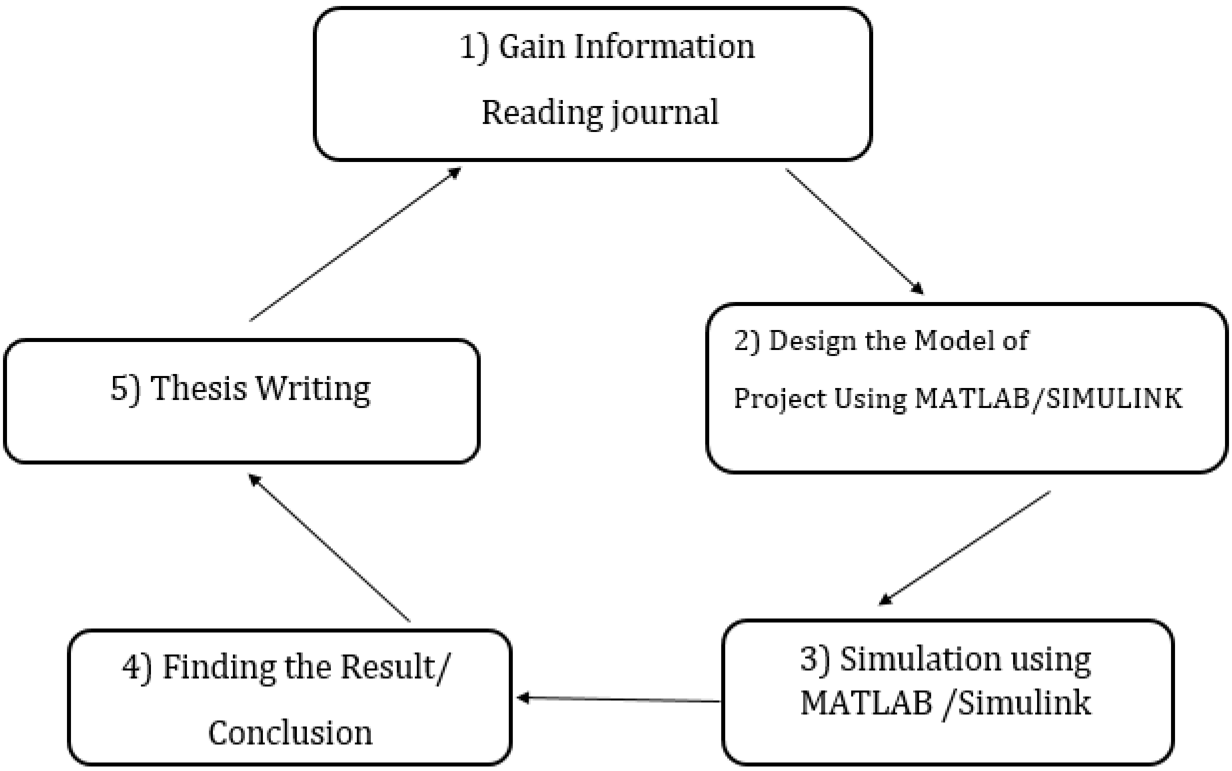

Figure 1.6: Project Flow Diagram

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will briefly review the study of previous researches in the form of journals and conference paper regarding to vector control (field-oriented control) technique for high performance IM drives, as well as aimed of the literature review, different implementation methods for controlling the three-phase induction motor are, in addition measurement that should be considered before implementing the project, the development of power semiconductor devices and the three-phase inverter, induction motor. Various aspects of senseless field-oriented control of induction machines are covered. They include the origin and nature of field-oriented control, power supply for senseless field-oriented control, controlled drives, switching tables for voltage space vector selection, stator flux and electromagnetic torque. Mathematical models of induction machines and principles of field-oriented control are mentioned only briefly in this chapter.

In this subtopic, the past works that were checked on and talked about originate from different journals. By referring to these journals, this project can be moved forward. The subtleties for each past work that have been done in a similar field were discussed in details in the following subtopic.

2.2 Classification of AC Motors

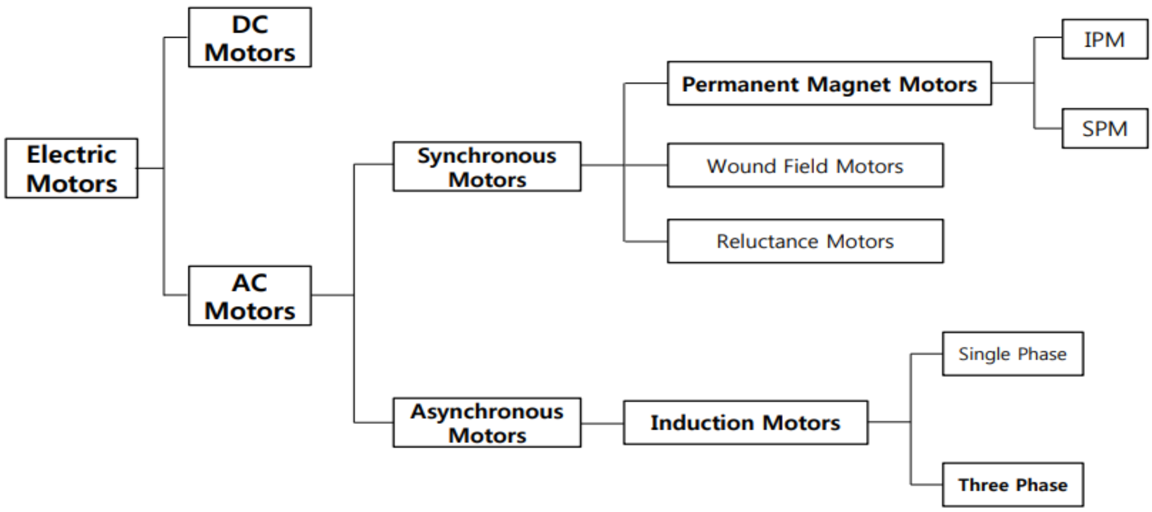

Figure 2.1: Classification of Electric Motors [19]

2.3 Induction Motors

Three phase induction motors are the most commonly used ac motors around, we will find them in literally thousands of applications-with the ability to produce a lot of torque, three phase induction motors typically power large industrial machines used for product manufacturing, processing and other applications [19]. Their simple construction, relatively low cost and low maintenance are the main reason for their popularity. Three phase ac induction motor consists of two major components namely stator and rotor, these components work together to convert electrical energy into mechanical energy [10] [11].

AC Induction Motor fabrication consists of two basic assemblies- stator and rotor. Inside the stator frame of the motor are the stator and the stator winding, the stator is made up of a series of stacked, insulated and compressed iron slices with cutouts or slots through which we run the stator winding [20]. The stacked metal slices are used to reduce electrical losses in the system. The rotor is basically a cylinder with an iron core which is also made up of laminated slices just like the stator [21]. The rotor has conducting end caps on each end and conducting bars running through the slots in the laminated slices that connect to the end caps. The result is a rotating cage that looks similar to a squirrel cage. That's why induction motor is commonly referred to as a squirrel cage motor. The rotor is attached to the motor shaft. Bearing support, the motor shaft allowing the shaft and roller to rotate as it remains centrally positioned within the stator enclosure. [22] The shaft transports the mechanical energy created from the rotor to the load and an air gap between the stator and rotor eliminates any physical contact between the two components [23].

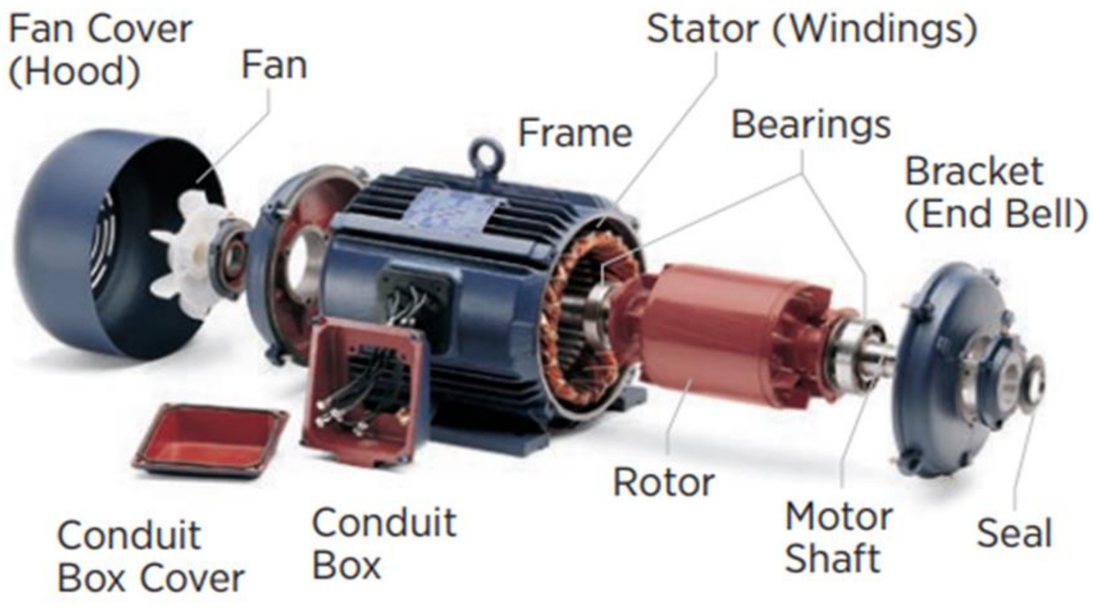

Figure 2.2: Induction Motor Construction

The enclosure is used for protecting the component which consists of the motor frame and the end bells. The end bells contain bearings which allow the rotor shaft to run freely on its axis. The type of enclosure can vary depending on the motor's application. There are two basic types of rotor winding concepts. The first type places the rotor winding slot with a slip ring on the shaft, the more common type consists of a rotor in a squirrel cage form. The principle of operation for an ACIM is established on voltage induction from the stator winding to the rotor. When the stator winding is feed by three phase alternating current, the current flows in the winding and the stator rotating magnetic field is generated. The speed torque characteristics display the ACIM reaction on the load, the representative induction machine speed_ torque characteristics is shown in the following Figure 1.2[24]. The first manner of characteristic division is by the machine states into the braking, motor, and generator regions. The appropriate operating point selection is in the midst of the speed torque characteristics of the stable part of the motor region. In this area the speed falls slightly with the load. It is obvious that from the characteristic, that the motor start torque is restricted. The full motor start torque can be achieved using an advanced FOC method [25].

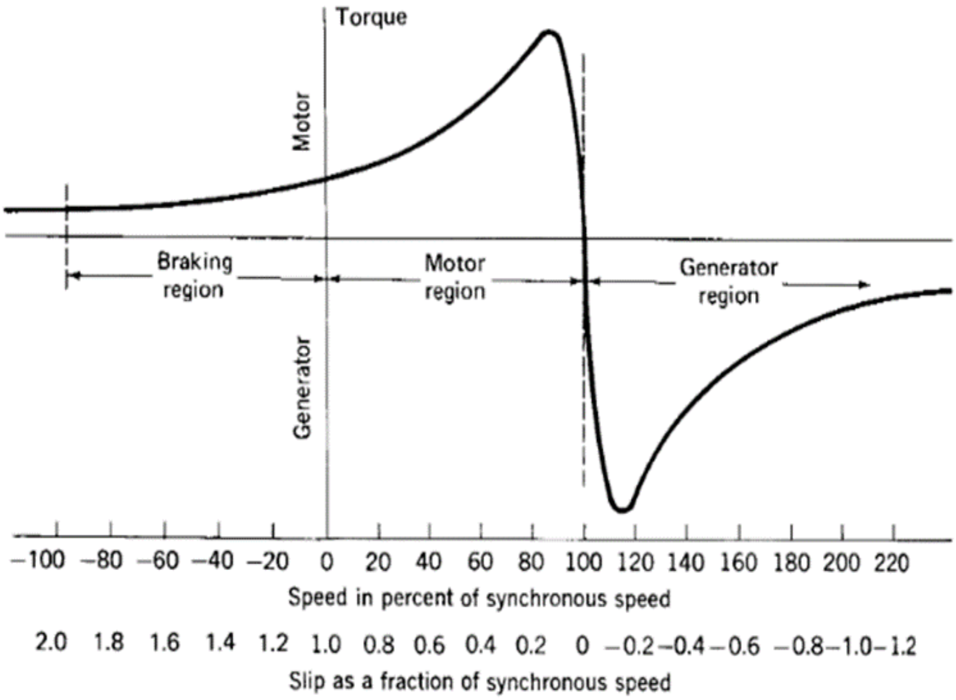

Figure 2.3: ACIM Speed Torque_ Characteristics

2.4 Induction Motor Control Strategies

There are a number of vector control strategies are obtainable in literature. Its control methods are divided in two groups, namely the vector control and scalar control.

1) Scalar control where magnitudes of the stator voltages and the stator frequency are the controlled components.

2) Vector control approach uses the space vector model of the induction motor to precisely control the torque both in steady state and transient operation [26].

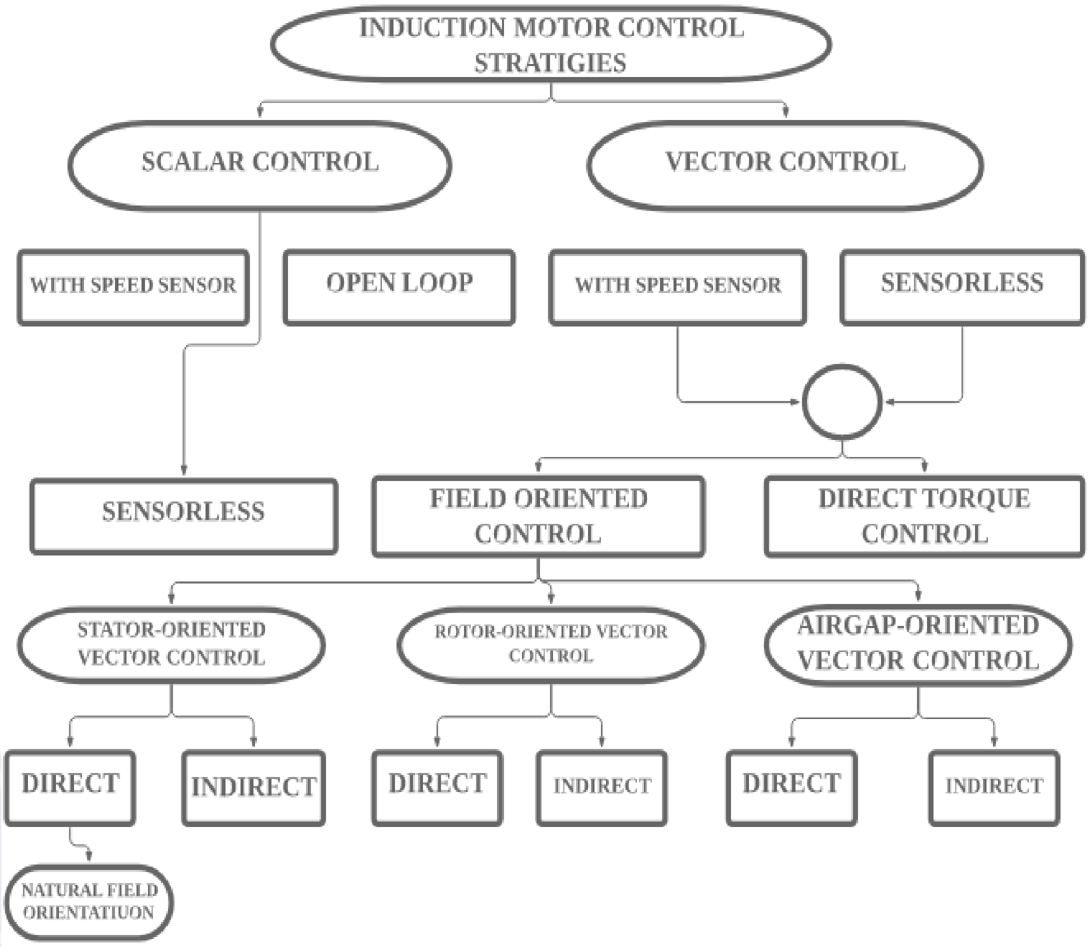

Figure 2.4: Classification of Induction Motors Control Strategies

2.5 Speed Control of Induction Motor

The speed control of induction machines necessitates a lot of complicacy than the control of dc motor, particularly if comparable accuracy is desired. The most reason for the same is attributed to the complexness of the mathematical model of induction machine, in addition

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